only been transferred from the steam boilers to the distilling apparatus, and that constant breakdowns of the latter necessitate the introduction of sea water into the boiler to eke out the supply of distilled water from the condensers.

The waters at present in use in marine boilers may be classified as—

(1) Sea water, (2) distilled water, (3) mixtures of sea water with distilled or fresh water.

In this paper the nature and causes of the deposits are studied in each of these cases.

Fresh water contains about twenty to fifty grains per gallon of dissolved solids, principally consisting of calcium carbonate, held in solution by carbonic acid present in the water, whilst sea water contains about 2300 grains per gallon, consisting principally of sodium chloride, together with magnesium salts and calcium sulphate. The wide difference in composition between fresh and sea water is also shown in the deposits formed by them. Analyses show that with fresh water the incrustation may be looked upon as consisting principally of calcium carbonate; that with a mixture of fresh and salt water the deposit consists of nearly equal parts of calcium carbonate and calcium sulphate; whilst the sea water gives practically calcium sulphate.

A deposit of calcium carbonate only, separates out as a soft powder, which remains suspended in the water for some time, and can fairly easily be removed from the boiler on cleaning; whilst calcium sulphate as formed in the boiler separates out in a crystalline form, and binds the deposit into a hard mass, so hard in fact that it requires the aid of a chisel and hammer to detach it from the plates and tubes, an operation which is extremely injurious, and tends to shorten the life of the boiler.

Calcium sulphate is much more soluble in a saline solution such as sea water than it is in fresh water, but its solubility rapidly decreases (1) on concentration of the saline solution, and (2) with increase of temperature and pressure.

Sea water having a density of 1·027 was evaporated, and analyses made at different densities with the following results:—

Saline Constituents per Cent.

Density ...	1·029	1·05	1·09	1·225
Sodic chloride	2·6521	4·4201	7·9563	23·8689
Calcic sulphate ...	0·1305	0·2175	0·3915	none
Calcic carbonate ...	0·0103	0·0171	none	none
Magnesic carbonate ...	0·0065	0·0032	none	none
Magnesic chloride ...	0·2320	0·3865	0·6960	2·0880
Magnesic sulphate ...	0·1890	0·3150	0·5670	1·7010

So that on concentrating sea water at ordinary atmospheric pressure, three distinct stages may be traced:—

(1) Deposition of basic magnesic carbonate;

(2) Deposition of calcic carbonate with remaining traces of the basic magnesic carbonate and hydrate; and, finally,

(3) Deposition of the calcic sulphate.

If the sea water be heated and concentrated above a density of 1·225, the salt commences to crystallize out.

These experiments show that if sea water be boiled merely under atmospheric conditions, it would be quite possible, by taking care that its density does not rise above a certain point (1·09) to prevent the deposition of the calcium sulphate; but any such regulation of density is rendered abortive by the fact that pressure and consequent raising of the boiling-point acts upon the calcium sulphate in solution in exactly the same way as concentration, as it is found that this substance is perfectly insoluble in either sea or fresh water at a temperature of 150° C. In the present high-pressure boilers, even if the sea water be mixed with a hundred times its volume of distilled water, so as to reduce its density very low, deposition of calcium sulphate still occurs.

Analyses of several specimens of deposits from boilers where sea water was used, showed that in all cases there were two distinct layers—(1) a hard crystalline deposit on the sides of the tubes, consisting of nearly pure calcium sulphate in the form of "anhydrite"; (2) a softer portion resembling alabaster in the interior, consisting of calcium sulphate, with about 6 per cent. of magnesic hydrate.

The presence of magnesic hydrate in boiler deposits is supposed to be due to the mutual decomposition of water and magnesic chloride, later experiments have shown, however, that when magnesic chloride and calcium carbonate mutually react upon each other, soluble calcium chloride and magnesium hydrate are formed; this explains why calcium carbonate is never found, except in very small quantities in marine boiler deposits.

When distilled water only is used, a slight coating is formed, practically consisting only of organic matter, whilst if at any time through a break-down in the distilling apparatus sea water is mixed with the distilled water, a thin and very hard scale of calcic sulphate is formed. An incrustation of this character gave on analysis:—

Calcic sulphate	90·84
Magnesic hydrate	0·75
Sodic chloride	1·41
Silica	0·85
Copper carbonate	1·11
Oxides of iron and alumina	0·24
Organic matter	2·96
Moisture	1·84
	100·00

This scale is of great interest from the presence in it of the carbonate of copper. It is well known that distilled water has a far greater solvent effect upon metals than a water containing salts in solution, and it is quite conceivable that the distilled water from the surface condensers attacks the brass and copper tubes and fittings, and deposits the copper on the tubes of the boiler, although in only small quantities; and it is interesting to note that the green spots due to the presence of the copper are all on the under side of the scale—that is, in contact with the metal of the boiler tubes, showing that in all probability it had been deposited, as suggested, from the water in the boiler, and in contact with the iron would set up local galvanic action and tend to produce pitting.

The importance of preventing boiler incrustation, and thereby saving the enormous waste of fuel and injury which it entails, has not been without influence on the minds of inventors, and almost every conceivable substance, from potato-parings to complex chemical reagents, have from time to time been patented for this purpose, but have failed more or less for marine boilers, because either they have had an injurious effect upon the metal of the plates, or else have produced an enormous bulk of loose deposit, which, although easily cleaned out if the various parts of the boiler were accessible, and if it were only being used intermittently, yet in a marine boiler continuously working, rapidly chokes the portions between the tubes.

For these reasons, no treatment of the sea water in the boilers themselves is practically possible, and with high-pressure tubular marine boilers the water must be either condenser water, made up to the required bulk with distilled water, as is at present done, or else the condenser water must be augmented by sea water specially prepared for the purpose in a separate apparatus before being supplied to the boilers.

If the engines of a vessel are in good condition, she will approximately require 1 ton of water per 1000 horse power per twenty-four hours, to make up the volume of the condenser water to the amount required for the boilers, so that, even supposing the engines not to be in good order, and considerable waste to take place, 10 tons per diem would be an outside allowance for even very large vessels. To obtain this amount of treated sea water the author proposes an arrangement, full details and diagram being given in the original paper.

The sea water, containing 40 pounds of soda crystals to the ton is heated up under pressure in a separate apparatus by passing through the solution superheated steam. Under these conditions the precipitated mixture of calcium and magnesium carbonates becomes very dense and settles very quickly. The water is then forced through filtering frames into the hot well of the boiler and is then ready for use. The whole process is effective and rapid, and simple arrangements are made for flushing out the apparatus, after each batch of water.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

CAMBRIDGE.—The courses of science lectures this term are as numerous as usual, but present few noteworthy features. Mr. Gardiner gives a general course of Botany, while Mr. Darwin is conducting the course of Elementary Biology (Plants), the lectures being given in the Archæological Museum Lecture Room. Prof. Macalister is lecturing on the History of Human

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Anatomy, a subject on which a brief volume from his pen would be very acceptable. Prof. Foster's course is on the Physiology of the Senses this term.

Among the numerous courses of demonstrations in the Cavendish Laboratory we may note those of Mr. Wilberforce on Dynamo-Electric Machines (Alternating Current Generators and Transformers).

Two lectures will be given in the Literary Schools on June 4, and June 8 at 2.15 p.m., by Dr. Francis Warner, on the Study of Mental Action and the Classification of Pupils according to their Brain Power.

LONDON.—The following appointments of Examiners in various branches of Science in the University of London were made on Wednesday, April 24:—Prof. Hill and Dr. Larmor as Examiners in Mathematics and Natural Philosophy; Prof. FitzGerald and Mr. Glazebrook as Examiners in Experimental Philosophy; Dr. Pole and Sir John Stainer as Examiners in Music; Prof. Tilden as Examiner in Chemistry; *Prof. H. E. Armstrong, F.R.S., as Examiner in Chemistry; Prof. Bower and Prof. Ward as Examiners in Botany and Vegetable Physiology; Mr. Sedgwick as Examiner in Comparative Anatomy and Zoology; *Sydney J. Hickson as Examiner in Comparative Anatomy and Zoology; Prof. Boyd Dawkins as Examiner in Geology and Palæontology; *Prof. Charles Lapworth, F.R.S., as Examiner in Geology and Palæontology. The asterisks denote new appointments. The gentlemen to whose names no asterisks are prefixed held the same appointments last year.

SCIENTIFIC SERIALS.

American Journal of Science, April.—Contributions to meteorology, by Elias Loomis. In this paper, which was read before the National Academy of Sciences, November 14, 1888, the chief subjects discussed are the relations of rain areas to areas of high and low pressure. From these studies it appears generally that no great barometric depression with steep gradients ever occurs without considerable rain; that in great rain-storms the barometric pressure usually diminishes while the rainfall increases; that the greatest depression of the barometer generally occurs about twelve hours after the greatest rainfall; that a great rainfall is favourable to a rapid progress of the centre of least pressure. It also appears that in Great Britain the amount of rain with a falling barometer is twice that with a rising barometer; but this ratio diminishes rapidly eastwards, the precipitation in Central Europe being greater when the barometer is rising than when it is falling.—The sensitive flame as a means of research, by W. Le Conte Stevens. These experiments, which take as their starting-point Lord Rayleigh's memoir on "Diffraction of Sound" (Proceedings of the R. Institution, January 20, 1888), tend to show that the sensitive flame is not applicable for purposes of exact measurement, though it is much more nearly so than has been generally supposed. Without its aid it would have been impossible to establish the important analogies here shown to exist between light and sound.—The Denver Tertiary formation, by Whitman Cross. In this paper a succinct account is given of the newly determined Tertiary formation about the Denver district, Colorado, which had hitherto been assigned to the Laramie Cretaceous. Although of limited geographical extent, this formation possesses features of special importance in several respects. The vertebrate remains here occurring present some very remarkable associations, which appear to be in direct conflict with all past observations.—Events in North American Cretaceous history illustrated in the Arkansas-Texas division of the south-western region of the United States, by Robert T. Hill. Here are embodied the results of the author's investigation of the stratigraphic and palæontological conditions in the northern and eastern termination of the Texas Cretaceous, which are brought into relation with the corresponding formations in the Gulf and Western States.—The distribution of phosphorus in the Luddington Mine, Iron Mountain, Michigan, by David H. Browne. The results are here given of some 3000 analyses of ore from the Luddington Mine made during the last three years by the author while acting as chemist to the Lumberman Mining Company. Although no generalizations are attempted, these analyses tend to throw much light on one of the most difficult problems in the chemistry of iron ore—the distribution, throughout the vein, of Bessemer ore, and its relation to the formation of the deposit.—Papers were contributed by C. S. Hastings, on a general method for determining the secondary chromatic aberration for a double telescope objective, with a description of a telescope sensibly free from this defect; by G. Baur, on Palæohatteria, Credner, and the Proganosauria; and by O. C. Marsh, on some new American Dinosauria, with a comparison of the principal forms of the Dinosauria of Europe and America.

Bulletin de l'Académie Royale de Belgique, March.—On the discovery of some fossil remains of mammals anterior to the diluvium at Ixelles near Brussels, by Michael Mourlon. These deposits, brought to light in August 1888, were all found at a lower level than that of the rolled Quaternary gravels, and at some points were overlain by several beds of undisturbed shingle. They include remains of the cave bear, of *Elephas antiquus*, of *Bison priscus*, *Bos primigenius*, the hare, *Equus caballus*, and a smaller equine species here described under the name of *Equus intermedius*, altogether forty four individuals, representing five known and four not yet determined species, and presenting a general resemblance to the mammalian fauna of the English forest-bed.—On the physical properties of the free surface layer of a fluid, and on the contact layer of a fluid and a solid, by G. Van der Mensbrugghe. The experiments here described lead to results opposed to the capillary theories of Laplace and Poisson; they further show that the theory of Gauss is intimately associated with the surface tension of fluids, one leading inevitably to the other, and confirming the author's previous conclusion that the demonstrated existence of tension justifies the theory of Gauss.—Note on a theory of the secular variation of terrestrial magnetism deduced from experimental data, by Ch. Lagrange. Several arguments are advanced in support of the author's new hypothesis that the secular magnetism of the earth is due to a magnetic potential interior and not exterior to the surface of the globe. The solid globe itself is thus regarded as a magnet, or a solenoid—that is, as a magnetic body properly so called, or as a conductor traversed by circular currents.—A paper is contributed by P. De Heen on the determination of the theoretic formula expressing the variations of volume experienced by mercury with the changes of temperature.

Rendiconti del Reale Istituto Lombardo, March 28.—Influence of the digestive juices on the virus of tetanus, by Prof. G. Sormani. A series of experiments are described, which the author has carried out on rabbits, guinea-pigs, rats, and dogs, from which are drawn the following conclusions: (1) the flesh of animals dying of tetanus may be consumed with impunity; (2) the bacillus of tetanus swallowed by carnivorous and herbivorous animals passes through the system without causing death or any special disturbance; (3) the gastric juices of herbivorous animals neither kill, nor diminish the virulence of, the bacillus; (4) an animal may with impunity swallow a quantity of the virus ten thousand times more than would suffice to kill if introduced by hypodermic inoculation; (5) the facts here determined throw some doubt on the accepted theory that the effects of tetanus are due to the absorption of poisonous alkaloids derived from the bacillus.—G. Somigliana contributes a paper on differential parameters, explaining a process by which they may be formed, and demonstrating the invariability of those of the first order. Certain relations, either new or more general than those hitherto studied, are also established between the parameters of the first and second orders.

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, April 4.—"The Ferment Action of Bacteria." By T. Lauder Brunton, M.D., F.R.S., and A. Macfadyen, M.D., B.Sc.

The chief objects of this research were, (A) to discover whether microbes act on the soil upon which they grow by means of a ferment; and (B) whether such a ferment can be isolated, and its action demonstrated on albuminoid gelatine and carbohydrates, apart from the microbes which produce it, in the same way that the ferments of the stomach and pancreas can be obtained apart from the cells by which they were originally secreted.

The microbes used were Koch's spirillum, Finkler's spirillum, a putrefactive micrococcus, scurf bacillus, and Welford milk bacillus (Klein).

The results of the inquiry were as follows:—

(1) The bacteria which liquefy gelatine do so by means of an enzyme.

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